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Abstract: Surface design is commonly seen as pattern prints on textiles. Applications, materials and technologies involved in surface design are more intricate though, especially concerning three dimensional textiles comparing to conventional two dimensional textiles. Applying a similar structure of the engineered surface classification, it was possible to propose a classification of textile surface design, according to its functions and performance.

Keywords: Surface design, engineered surface, three dimensional textiles classification.

1. Introduction

While surface design is commonly used in relation to pattern prints on textiles, any surface that has a design can be defined as a surface design. This is regardless of the base material, with either a two dimensional or three-dimensional structure. Surface design is a term vastly used in fashion design but this term can equally be applied to any textiles for interior design, architecture, and even automotive or medical products, as much as other materials in engineering, product or graphic design (Ruthschilling, 2002; Rubim, 2004; Rüthschilling, 2008; Schwartz, 2008). For Rowe (2009) the fabric surface is an integrated part of the whole and should be seen not just as an aesthetic function of the product but also as a statement of the quality of the textile.

Since anything that can be seen, used or touched can be considered as a surface, textiles with 3D effects can also be considered a surface design (Briggs-Goode, 2011). Three dimensional (3D) textiles have been more widely explored by designers in the last two decades with several functionalities which are expanding their boundaries and applications. Structured, textured or engineered surfaces are considered by Evans and Bryan (1999) as surfaces "designed with specific textures to give specific performance", but to microstructure and nano scale. Reflecting on the "relationship between surface texture and function" they focus on the micro to nano scale and analyse methods and techniques to develop surfaces with a different range of applications (Evans e Bryan, 1999).

For Stout and Blunt (2001) engineered surfaces can be defined as "surfaces produced in specific ways that deliberately alter surface and sub-surface layers to give a specific functional performance". Although the 'engineered surface' is a well-established term for microstructures, this definition could be applied to other surfaces, such as three-dimensional textiles.

This paper aims to include and propose a classification for the surface design of textiles, explicitly including three dimensional textiles like knitted, woven, braided and non-woven textiles instead of limiting this to pattern prints. As 3D textiles is expanding within and beyond technical textiles and is still novel and innovative, it would benefit from classification. Comprehending 3D textiles as surface design is an attempt to clarify possible applications and expand its uses, which is not only for academic purposes, but also has commercial and technical benefits.

2. Surface design

When thinking of surface design in relation to textiles most designers understand it as pattern prints with aesthetic and symbolic functions. Since in surface design it is very common design for continuous surfaces such as fabrics, carpets and wall papers, it is easy to understand such understatement (Rubim, 2004). According to Rüthschilling (2008) the origin of the expression surface design was restricted to the textile design. As reported by Rubim (2004) surface design involves textile design in all specialties, and also covers design of papers, ceramics, plastics, rubber and can even be combined with graphic design, such as in illustrations or website interface. Rüthschilling (2008) also states that as surface become more important in everyday life, the term surface design is no longer restricted to only a specific material.

Schwartz's (2008) expand surface design definition by analysing according to three different approaches: (1) how it is represented: the representational approach; (2) according to materials and manufacturing processes: the constitutional approach; and (3) according to the relation between user, object and environment: the relational approach. Therefore, analysing surface design according to these approaches, it needs to be addressed not only regarding aspects related to the form or relation to the user/subject, but also to the criteria necessary for its production (Schwartz, 2008). To Laranjeira e Marar (2014) surface design is an interdisciplinary area with multiple subdivisions according to the formal composition of the object, the materials, techniques and manufacturing processes used in the development of the project.

Surface design is constantly evolving, which allows new applications in the most different media and scales, showing the importance of understanding, researching and developing new types of surfaces. For Rüthschilling (2008) the surface can be perceived as two-dimensional or three-dimensional with visual, tactile, functional and symbolic properties. To Rubim (2004) any surface can receive a surface design project, which is mainly two-dimensional, but can also be three-dimensional and its function is mainly aesthetic. However, with textile advances it can now be two or three dimensional and have practical or technical functions as well.

Most 3D textiles with technical functions are developed with an engineered design approach and its commercial use is still limited (Chen, 2015). In order to expand the market of 3D textiles to other applications that enable it to achieve their full potential, a new approach that takes into account aesthetic demands in addition to its technical functions can be necessary. By including three dimensional textiles as part of surface design textile classifications might help with this new approach.

3. Engineered surface

The engineered surface is concerned with textures with a particular functioning, functionality and manufacturing processes. Both Stout and Blunt (2001, p.2041) and Evans and Bryan (1999, p.543) support and identify surface classifications. Stout and Blunt (2001, p.2041) propose eight classifications, within a hierarchy, identifying the manufacturing processes and a group of properties for each surface classification. This classification focusses on the microstructure of surfaces produced by the manufacturing process that gives the surface a specific performance (Evans and Bryan, 1999, p.541).

As the properties, functions and manufacturing processes are associated with each class and sub-class, it is easier for designers, engineers and architects to understand and apply these to the development of new surfaces (Stout and Blunt, 2001, p.2040). The engineered surface classifications by Stout and Blunt (2001, p.2040) and Evans and Bryan (1999, p.543) help to reduce the ambiguity of surface description. Bruzzone *et al.* (2008) consider engineered surfaces complexity and their relationship between functional properties, applications and productive technologies, showing its advances and emphasize the importance of understanding and controlling its structuring methods.

4. Three dimensional textiles

Three-dimensional textiles can be produced by using different methods such as weaving, knitting and braiding and, in general, are manufactured for technical applications in industrial textiles, such as, fiber-reinforced composites (Gokarneshan e Alagirusamy, 2009) and functional clothing for sports or protection (Chen, 2015). Visual and aesthetic functions of three-dimensional textiles are more evident in garments for fashion design and soft textiles for interior design. Chen (2015) specify 3D textiles as a material that “have either an overall 3D shape or a more complex internal 3D structure or both “ and it can be single-layer or multiple layer, hollow or solid.

Currently, a lot of research in textile surface is carried out by designers and engineers exploring the relationship between the surface and the structure of fabrics, using the versatility of textile as a creative medium (Gale e Kaur, 2002). According to Maciel *et al.* (2016) “the extent to which 3D textiles can be designed and produced is allowing a dramatic increase in the development of structures with several functionalities”.

In 1960, 3D knits were first applied to engineering projects, even though they were developed in the nineteenth century. Three-dimensional knit can be obtained using different technologies and methods. According to Ionesi *et al.* (2010) the knitting methods that can be used to produce a third dimension are: (1) multi axial, with the insertion of additional yarns in several directions; (2) sandwich or spacer, with the knitting of independent layers connected by wires or by the structure itself; and (3) 3D effects, with the knitting of tubes or shapes and volumes by altering structural parameters.

Three-dimensional knit or knits with 3D effects can be produced in various ways, both in circular or flat knitting machines. Three-dimensional knitting allows for modification of the surface, creating layers, thickness, resulting in countless outcomes depending on the material (Maciel, 2014). 3D knits as a textile surface can be applied to various technical fields, such as aeronautics, automotive, medicine, construction and protective equipment (Ionesi *et al.*, 2010; Penciuc *et al.*, 2010; Blaga *et al.*, 2011; Ionesi *et al.*, 2012).

Three-dimensional woven fabrics have been widely used as composite structural components in aviation, civil engineering, sports and other areas. There are plentiful ways to produce 3D textile composites, and weaving is the most common method for high production speed and flexibility, which allows for the creation of a large range of structures. Three-dimensional woven fabrics are used for composite textile applications due to their excellent physical, mechanical and thermal properties and dimensional stability, among other characteristics. This performance depends on the type of fiber and the construction of the composite structure (Gokarneshan e Alagirusamy, 2009; Ansar *et al.*, 2011). Extending the application of three-dimensional woven fabrics, in addition to composite applications, can lead to new developments, structures and effects as well as new techniques and features.

According to the skills of each designer, creativity and needs, different applications and functionalities, the combination of such techniques can be used to develop other techniques that lead to different shapes and 3D effects (Penciuc *et al.*, 2010). Furthermore, it is important to emphasize that, increasingly, designers have been developing 3D textiles which have both strong technical and aesthetic functions, creating new products that are more appealing to the user. According to El Mogahzy (2008), this presents a design challenge to balance functionality and styling simultaneously. Bringing three dimensional textiles to be discussed and classified as surface design might contribute to an understanding of such a novel category in textiles.

5. Textile surface design classification

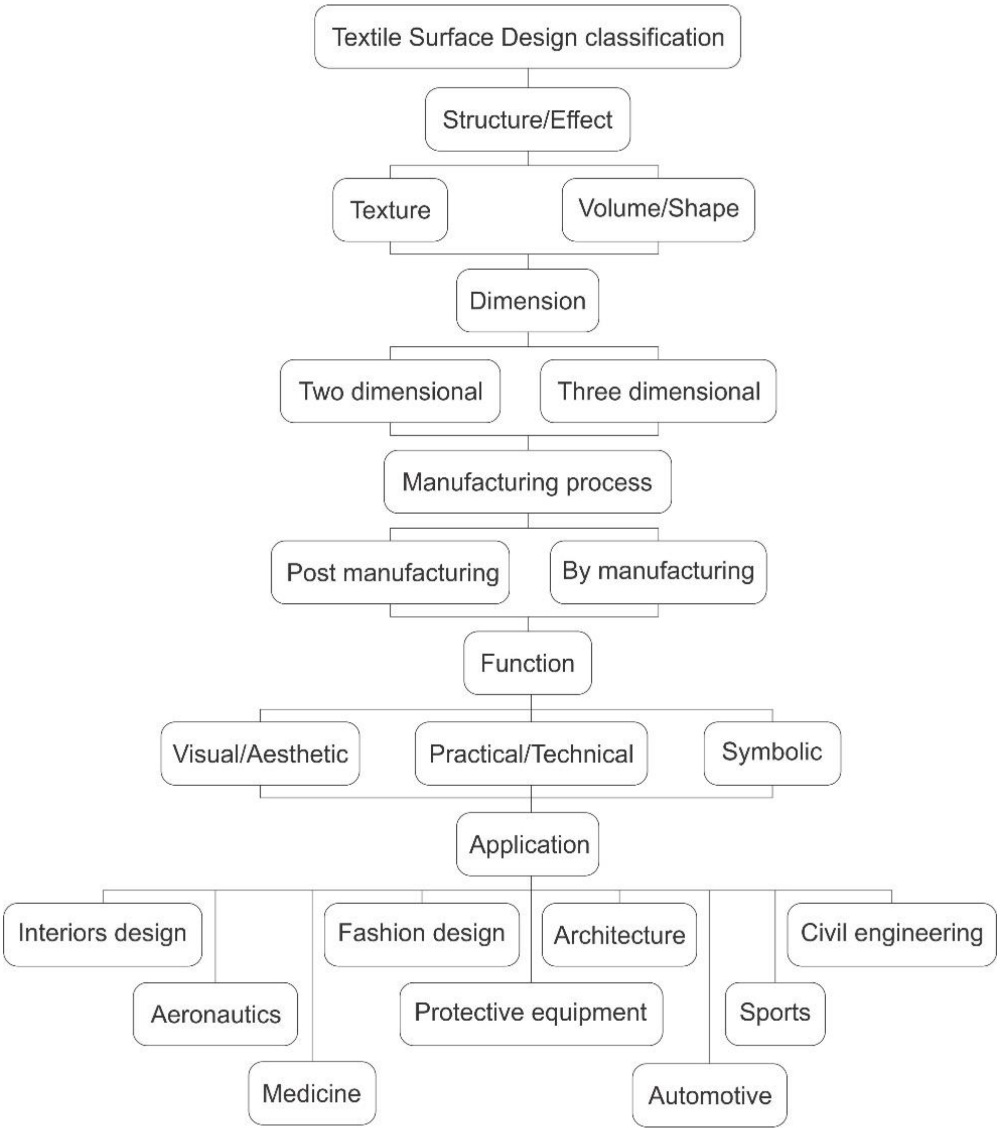
Surface design should be planned as part of the object and, therefore, follow a similar methodology as any other new product development does, to value the object by its surface and functionalities. The approach to the design of a surface can be driven by the ability to stimulate sensations and perceptions, so that it is considered an elaborate, designed element (Maciel, 2014). Thus, surface design should cover all kinds of intervention on the surface of a product or structure, such as textures, prints and laminate finishes of textiles. With that said, the development of three-dimensional textiles is therefore integrated into the surface design definition.

Since the engineered surface is used more for nano to small scale it’s unlikely that it can be transferred directly to classify surface design. Still it is relevant to have textiles defined within surface design according to a similar hierarchical classification, according to their structure/effect, dimension, manufacturing process, functions and applications. This in an attempt to combine Stout and Blunt’s (2001) and Evans and Bryan’s (1999) engineered surface hierarchy classification to the surface design concept and definition that is currently in use (Rubim, 2004; Rüthschilling, 2008; Schwartz, 2008; De Freitas, 2012). Defining all the manufacturing processes and applications that can be used to create new surfaces of textiles is out with the scope of this paper, instead the aim of this paper is to advance the understanding of the role of textile surfaces by proposing a new grouping of textiles surfaces and definitions.

Considering that 3D textiles is a field of increased development it is recognised that defining it will not be an easy task. However, it is important to provide some definitions for surfaces and applications of 3D textiles. A new approach of textile surface design that focusses on the manufacturing processes and functionalities can support the establishment of three-dimensional textiles as surface design and increase its applications, research and development as main focus of new products.

By combining the engineered surface classifications to surface design classification for 3D textiles, focusing on its functionalities, the first group proposed for the surface design hierarchy classification as illustrated in figure 1 is Structure/Effect, which can be a texture or volumes/shapes. All surfaces have texture, and with textiles it is not only easy to notice, texture is used as an embellishment, where extra volumes and shapes on the surface of the fabric can be produced. However, the difference between textures and volumes and shapes goes beyond the manufacturing process and the tactile perception, changing the dimension of a fabric from two to three dimensions.

Figure 1 - Textile surface design classification hierarchy.



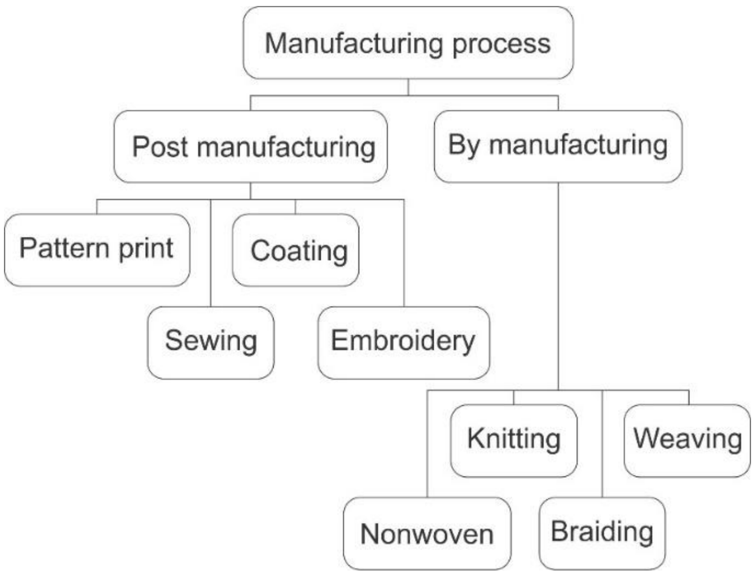
The structures and effects on the fabric surface can be classified as a texture when they are a consequence of a manufacturing process that does not significantly change the thickness or number of layers of a fabric and therefore should be classified as two dimensional. Pattern print, coating and embroidery are post production processes that can add texture to a fabric but do not change its dimension, and should, hence, be considered as two dimensional.

To be considered as three dimensional a surface should be changed in its structure or have effects that interfere significantly in the thickness of the fabric, creating layers, volumes and shapes. Knitting, weaving, nonwoven and braiding are manufacturing processes that produce a texture on the surface, but can also be used to produce shapes and volumes that will alter the thickness of the fabric. Sewing is the most common post production process to interfere in the structure of a fabric creating 2D or 3D effects.

The function of the surface can be visual/aesthetic, practical/technical and symbolic. As for the applications, with the outgrowing development of materials and technologies the ones sub grouped on **Error! Reference source not found.Error! Reference source not found.** are only a few that are currently being developed.

The manufacturing process classification has its own sub grouping (**Error! Reference source not found.**), as there are so many processes. The ones specified here are limited to the main manufacturing processes applied to textiles. The textile surface design can be produced with a post manufacturing process (pattern print, sewing, coating, embroidery etc.) and as part of a manufacturing process (knitting, weaving, nonwoven, braiding, etc.).

Figure 2 - Textile manufacturing process classifications.



It is not feasible to include all the textile surface design functions and applications developed so far. Therefore, this shows that more classifications can be included identifying new sub-groups, definitions and classifications, either with other types of materials, manufacturing processes or applications. By using the classification proposed designers, engineers and architects can identify different possibilities and applications for textile surface designs with new functions and attributes.

6. Conclusions

Surface design is an expanding field and with the constant development of new materials and technologies it will keep developing. For that reason, continuous definitions and classifications should be developed as it expands. On textile and other products and materials, surface design is usually associated to pattern print, but it is much more than that. Researching surface design definitions shows that more definitions should be addressed to three dimensional textiles.

The engineered surface classification has been used in this paper to illustrate a possible approach to organise definitions to support and include three dimensional textiles in the scope of surface design. With the engineered surface definitions used on a nano and micro scale with specific functionalities, it shows that the many applications, functionalities and possibilities that the three dimensional textiles exhibit so far is a good way to apply to textile surface design.

The classification proposed in this paper is not by all means complete or definitive. On the contrary, future contributions and modifications will be necessary. This indicates the assortment and potential of textile surface design and the increasing significance this field has, especially with three dimensional textiles and its applications. The structure and hierarchy suggested on this paper will support upcoming research in three dimensional textiles to a development that explore its performance for interior design applications.

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